



Validation Using IPHEX and OLYMPEx Multifrequency ER-2 Radar Observations

Gerry Heymsfield
Goddard Space Flight Center

Lin Tian: GESTAR/Morgan State Univ.

collab.: Mircea Grecu: GESTAR/Morgan State Univ.

thanks to: Bob Meneghini, Liang Liou, Ian Adams..

Presentation

- Use IPHEX and ER-2, *in situ*, and ground based radar measurements to help understand the DPR & GMI retrievals.
- Focus on a variety of cases with stratiform, orographic, and convection.
- Two convection cases (IPHEX and OLYMPEX)
- Explore the utility of LDR measurements for additional information on hydrometeor characteristics not provided by DFR.
- Retrievals using IPHEX/OLYMPEX data (with Grecu)

Challenges Observing Convection

- Storms can produce intense rainfall in localized regions < 10 km across.
- NUBF present for most convection for DPR and GMI.
- Attenuation, multiple scattering, etc.
- *A priori algorithm assumptions in the ice and mixed phase regions (particle size, density, PSD, habit, etc.) is still a major challenging problem in satellite algorithms.*

→ Use aircraft radar/radiometer measurements to improve understanding.

ER-2 Measurements from IPHEX & OLYMPEX

- ER-2 radars: multiple frequencies X to W band using 3 radars
HIWRAP, CRS, EXRAD
 - MC3E (2011) -> Ka and Ku band, *no polarization msmts.*
 - IPHEX (2014) -> W, Ka, Ku, X band; *Ka and Ku linear depolarization (LDR)*
 - OLYMPEX/RADEX -> W, Ka, Ku, X band; *W, Ka and Ku LDR*
→ calculate DFR, LDR, DDV, etc.
- Calibration: combination of internal and external (ocean).
HIWRAP Ku/Ka and EXRAD have internal calibration loop so every pulse has calibration; CRS had mechanical internal calibration loop so calibration was performed periodically during flight.

OLYMPEX ER-2 and DC-8 Radar Comparison

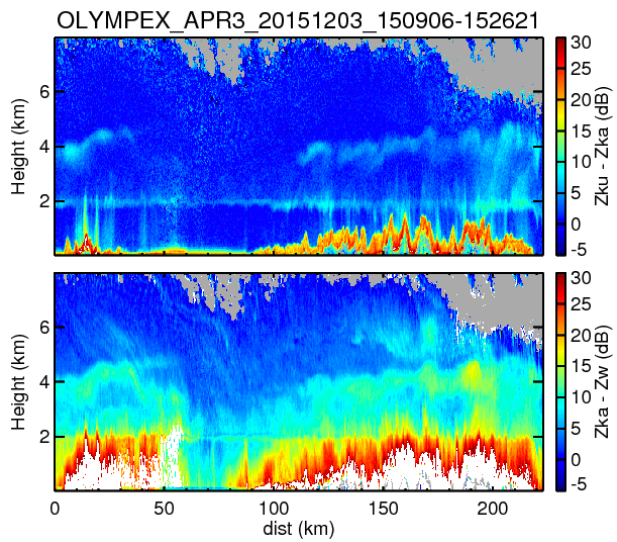
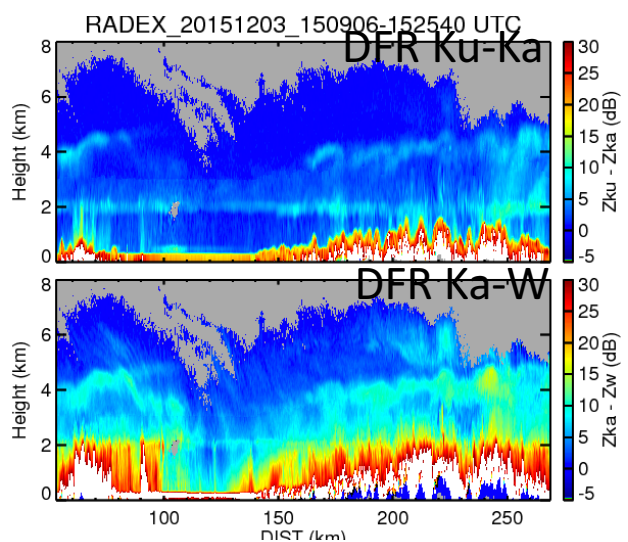
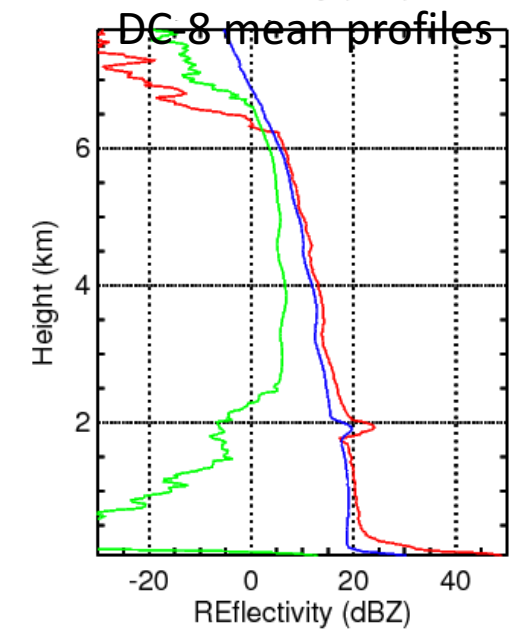
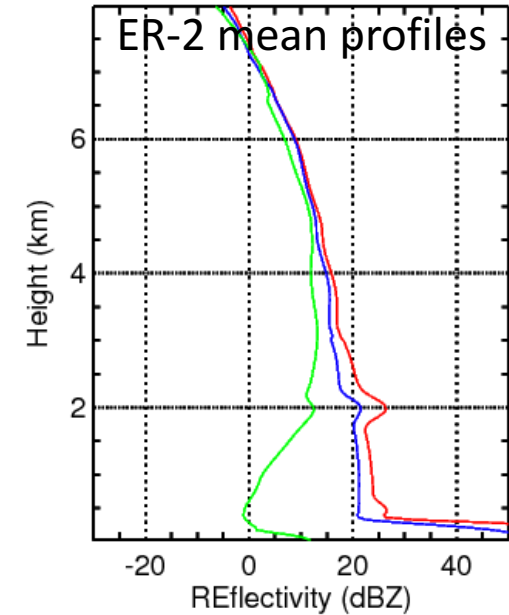
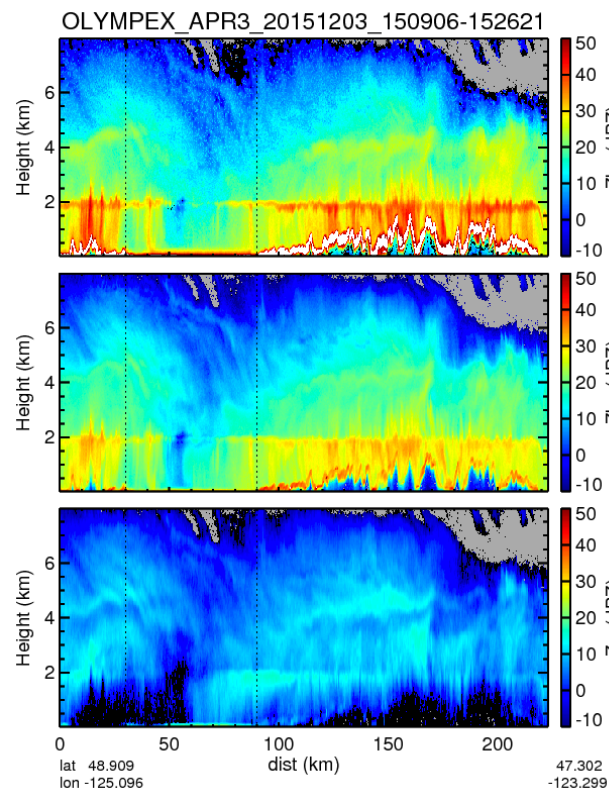
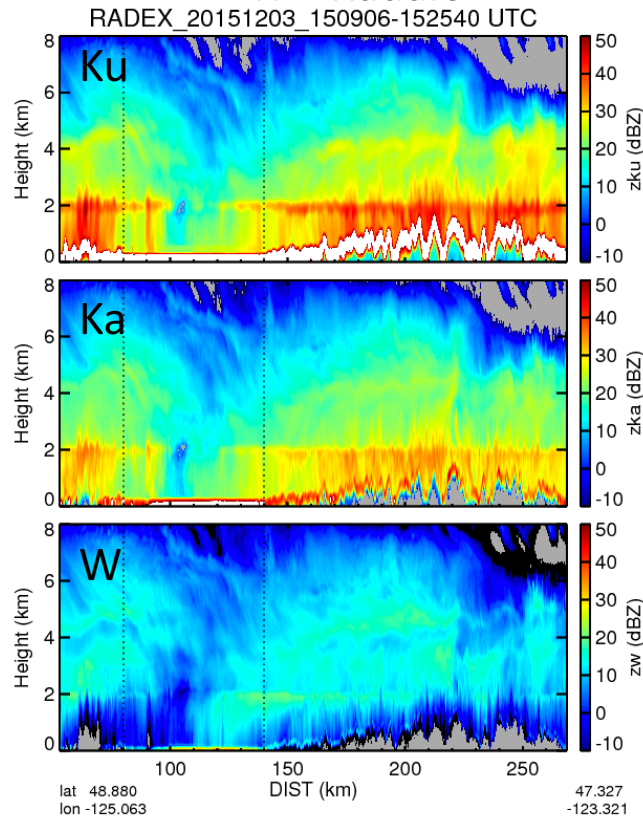
ER-2 Radars

DC-8 APR-3

OLYMPEX/RADEX

3 December 2015

ER2, Mean profile: d= 80-140



LDR and DFR

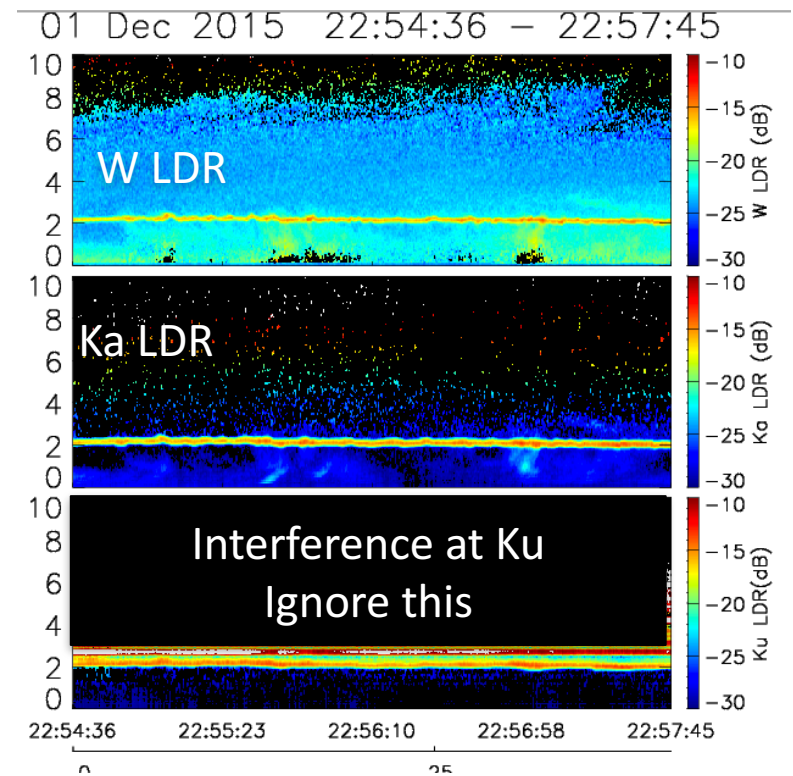
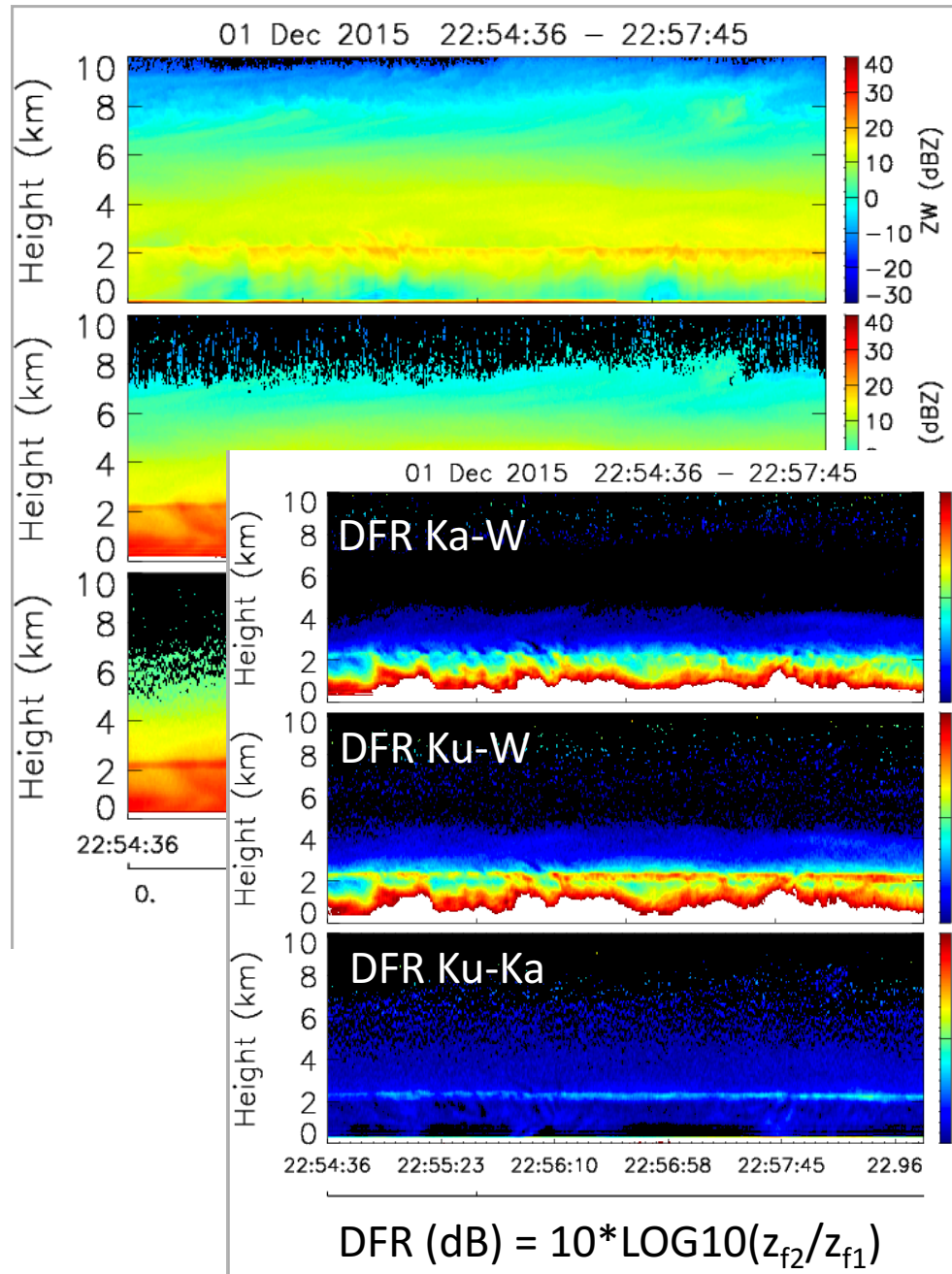
DFR (dB) = $10 * \text{LOG}_{10}(z_{f2}/z_{f1})$, where f is frequency

- Primarily depends on particle size from Mie scattering, but other factors such as particle shape, phase, and bulk density.
- Requires differential attenuation correction.

LDR (dB) = $10 * \text{LOG}_{10}(z_{VH}/z_{HH})$, where z is in mm^6/m^3

- Primarily provides information on particle canting angle, but particle size, shape, phase, density, and non-sphericity also very important.
- Tumbling, wet non-spherical particles such as hail, melting aggregates, wet graupel, and bright band due to melting (e.g., Vivekanandan et al.. 1990; Zrnic et al. 1993) produce large LDR values whereas light rain, cloud droplets, and dry ice particles are associated with low LDR values.
- Non-sphericity becomes more important with increasing wavelength.
- Requires differential attenuation correction although less so at nadir.

OLYMPEX
1 December 2015
Stratiform over ocean

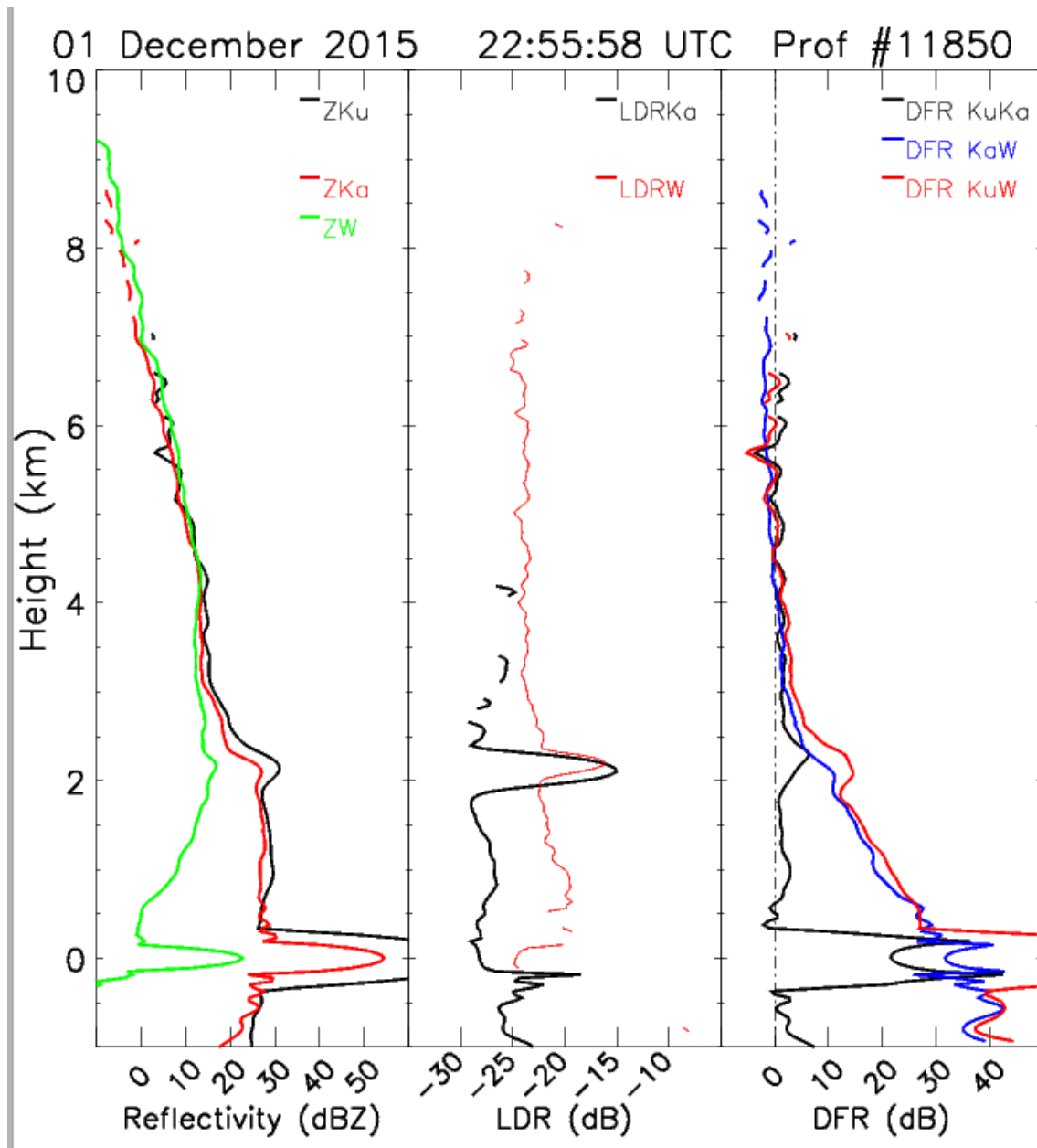


$$\text{DFR (dB)} = 10 \cdot \text{LOG}_{10}(z_{f2}/z_{f1})$$

$$\text{LDR (dB)} = 10 * \text{LOG}_{10}(z_{\text{VH}}/z_{\text{HH}})$$

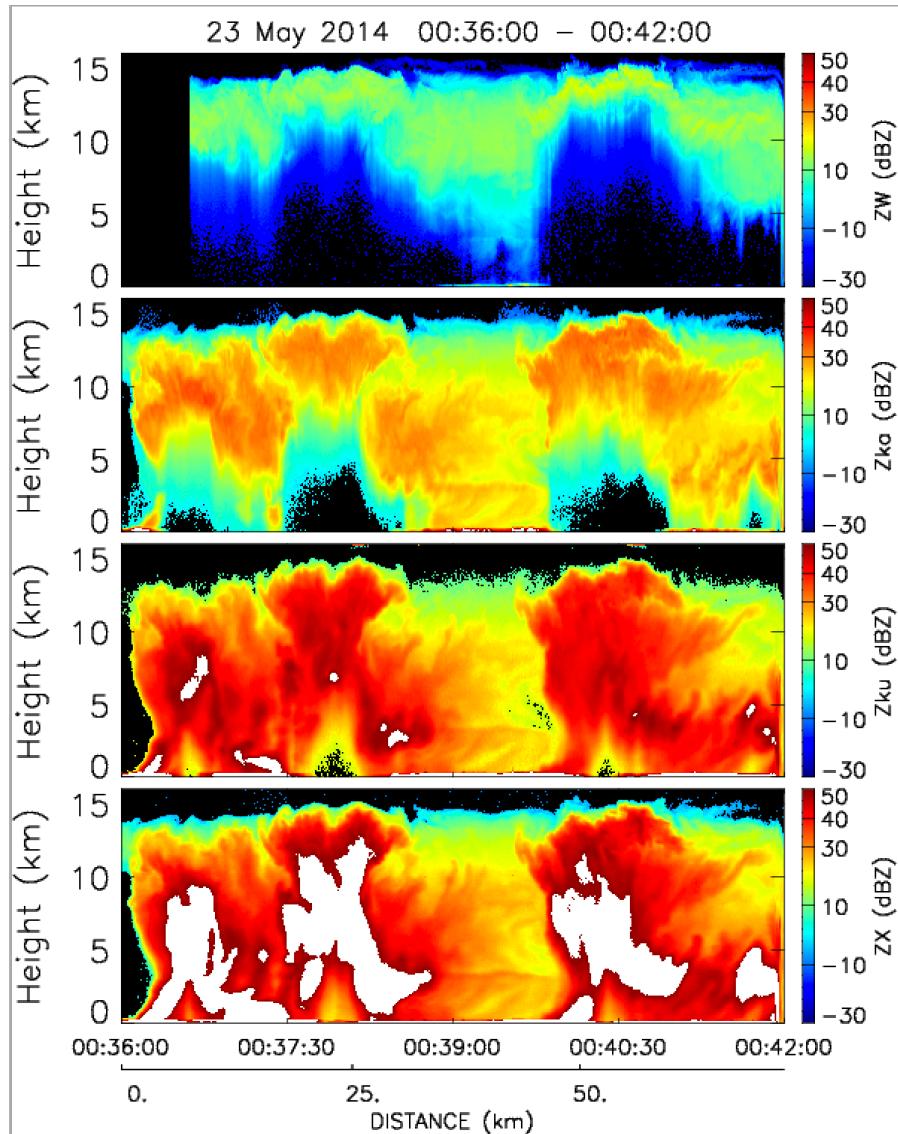
→ **LDR in melting layer caused by wobbling wet snow.**

OLYMPEX 1 December 2015 LDR & DFR

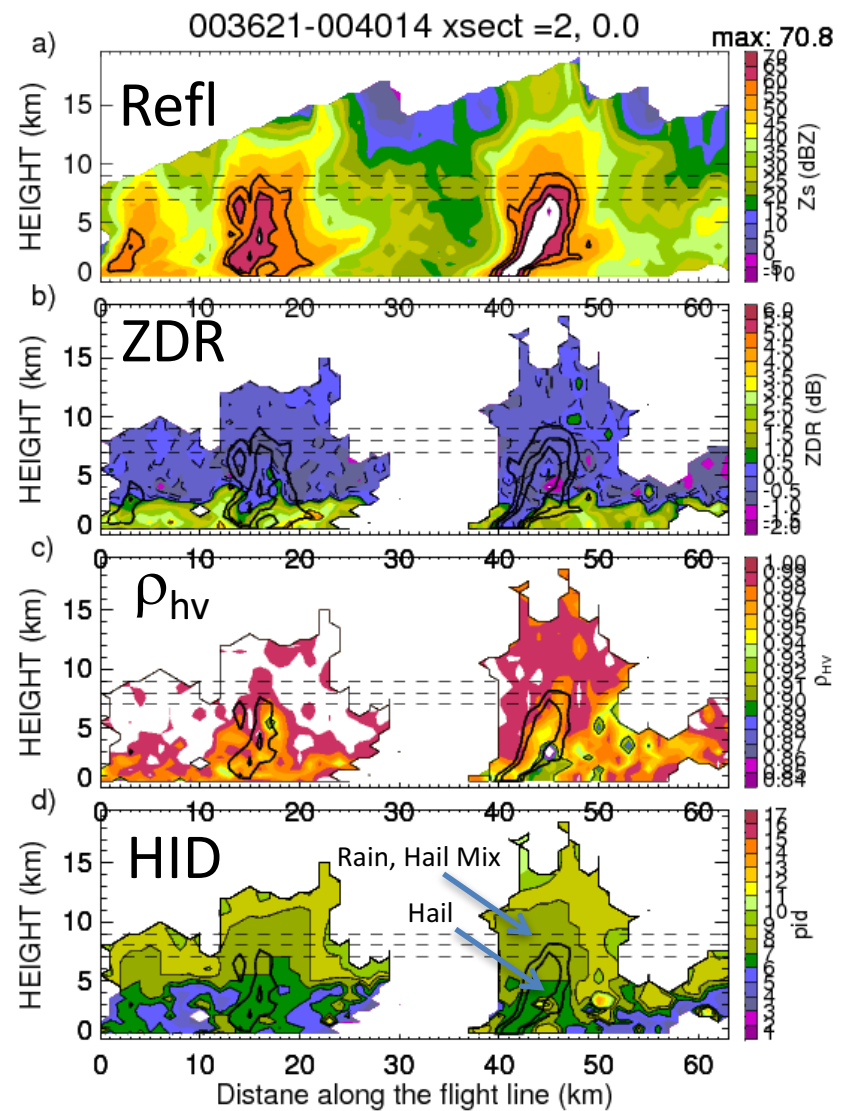


23-24 May 2014 – Hail Storms

ER-2 Radars



NPOL Polarimetric Radar

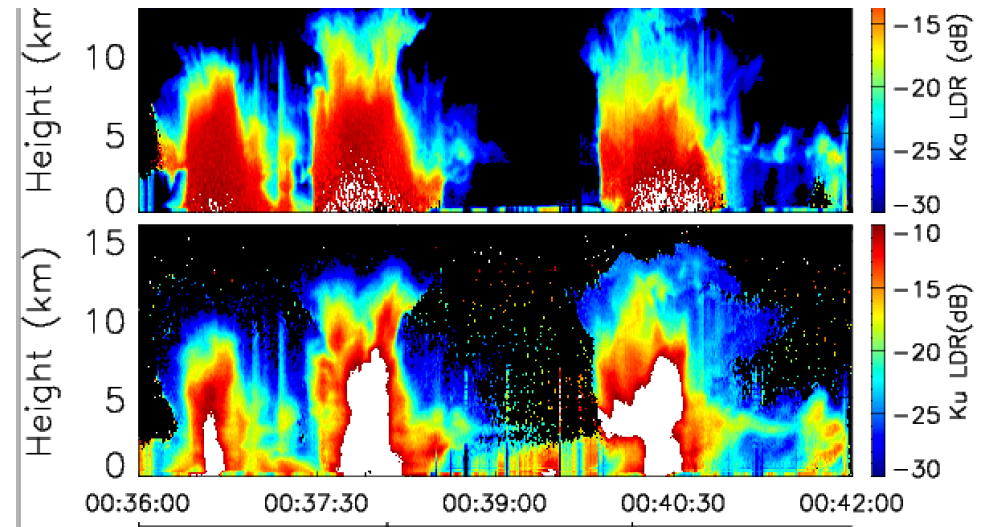
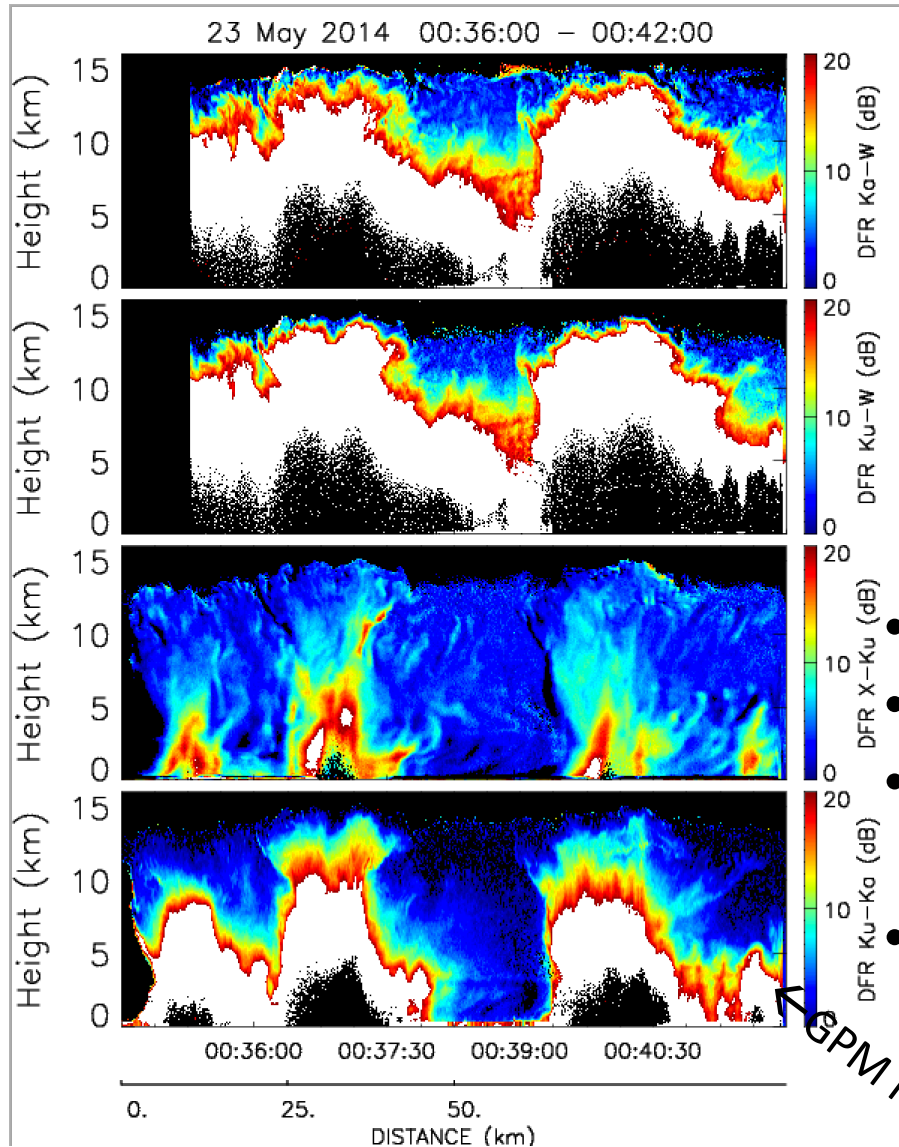


c_level=[55 60 65]

24 June 2014

DFR

LDR

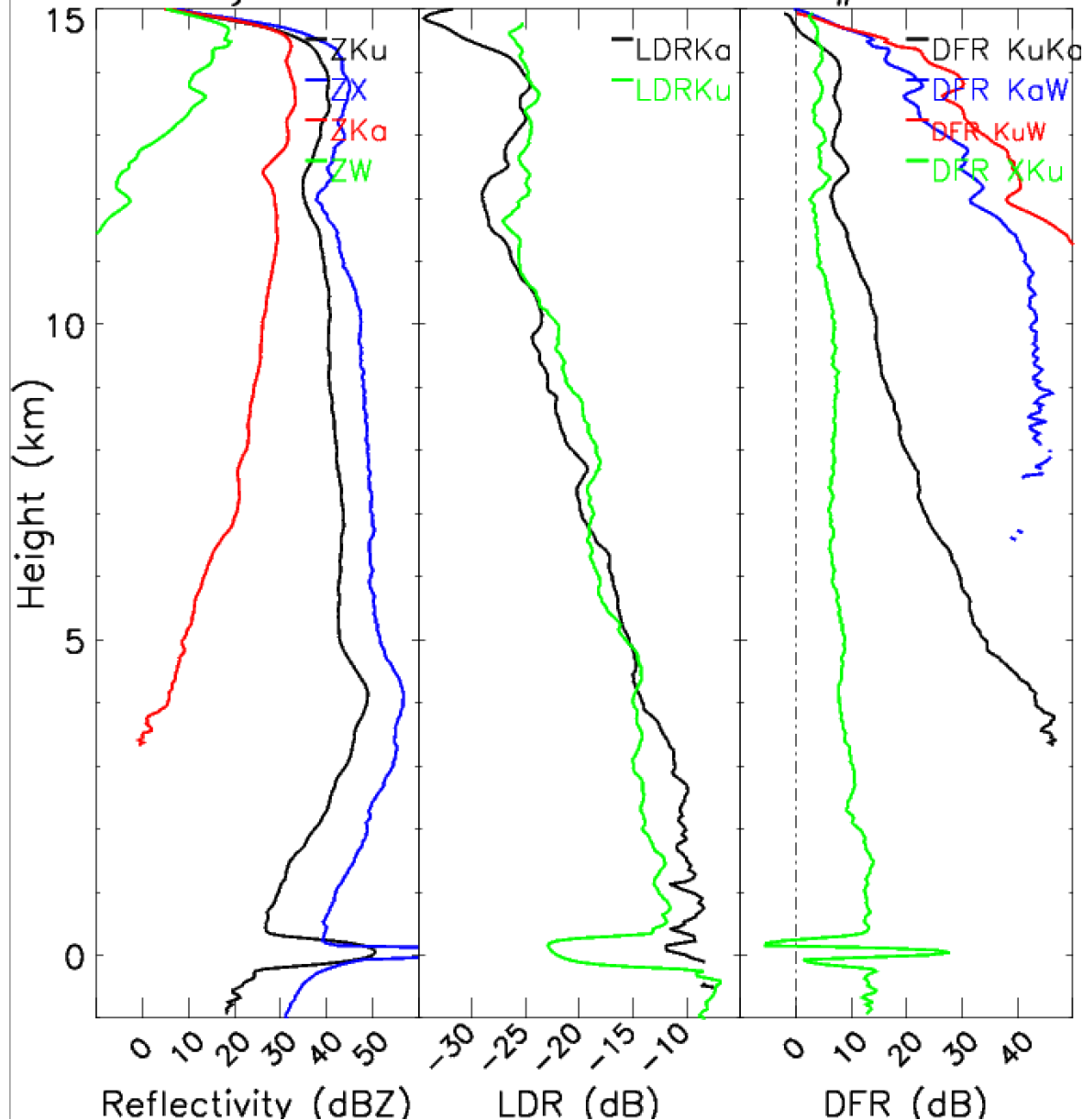


- DFR NOT corrected for attenuation
- DFR consistently broader than LDR.
- LDR “columns” (Jameson et al. 1996, Bringi, etc..)
- More spherical, less canted particles on edges of updrafts.

← GPM Freqs

IPHEX 24 May 2014 Hail Storm

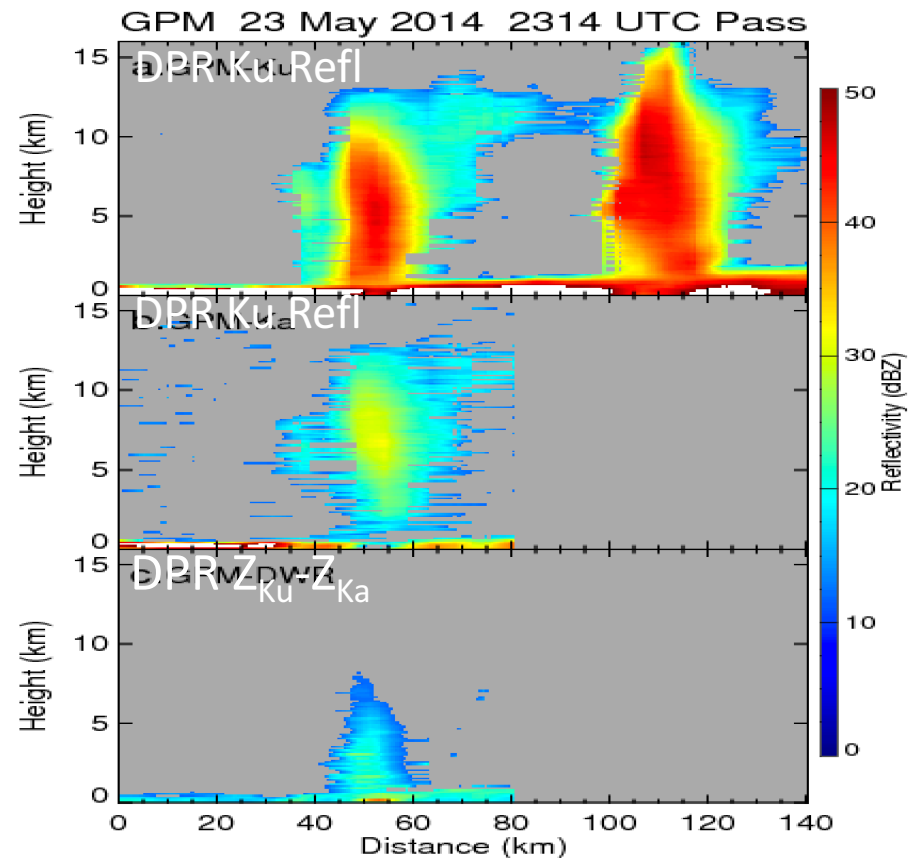
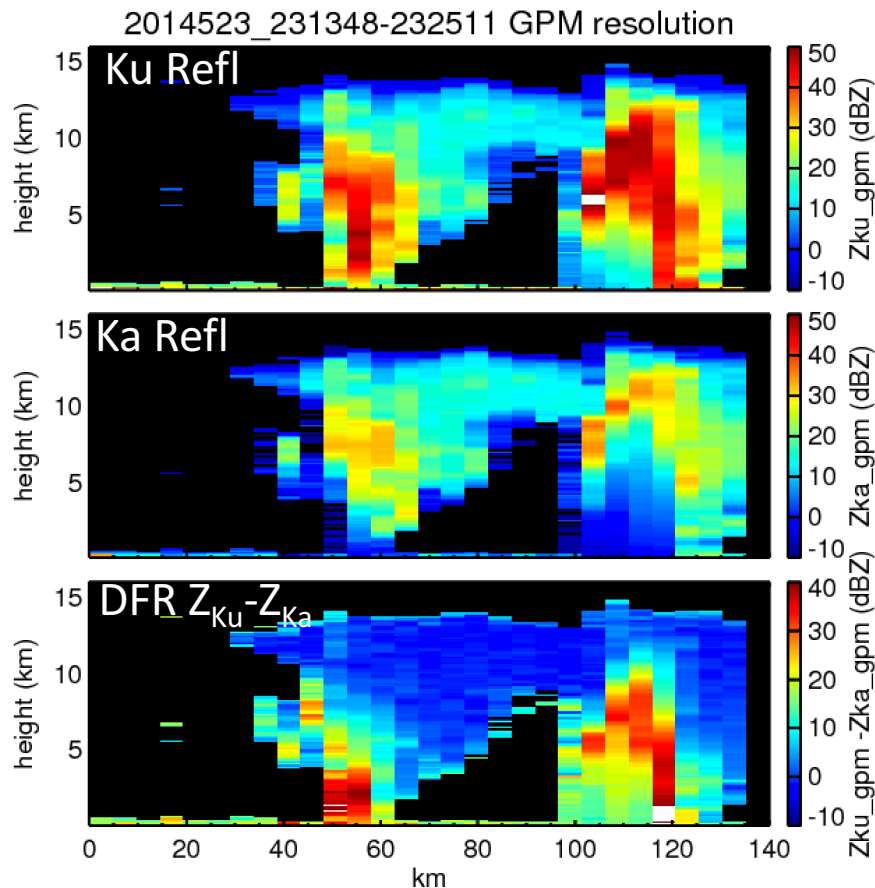
24 May 2014 00:40:37 UTC Prof #09163



- Battaglia et. al. 2014, 2016. Multiple scattering using these aircraft data sets.
- Ito, Oguchi, Iguchi, Komagai, and Meneghini (1995) → multiple scattering detected in Ka LDR.
- LDR clearly shows multiple scattering below 12 km.

23 May 2014

HIWRAP: DPR Resolution & DPR: 2321UTC

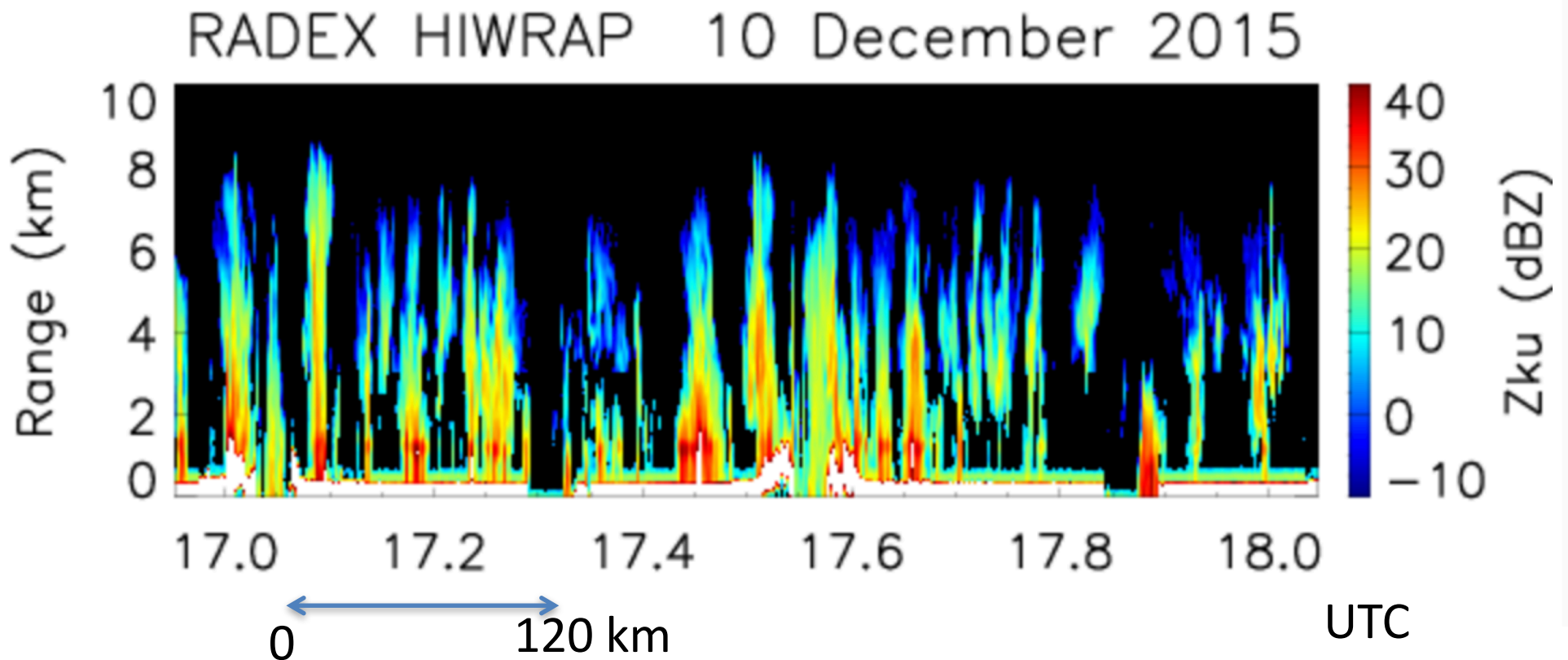


DPR flag heavy precip will be evaluated for these storms.

DPR Data: Special level-2 products provided by Drs. Kubota and Iguchi due to DPR sidelobe reduction test period.

OLYMPEX 10 December 2015

Post Frontal Convection



How well do DPR & GMI algorithms work on this cold season convection?

OLYMPEX 10 December 2015

20151210 17:00:00-17:29:59

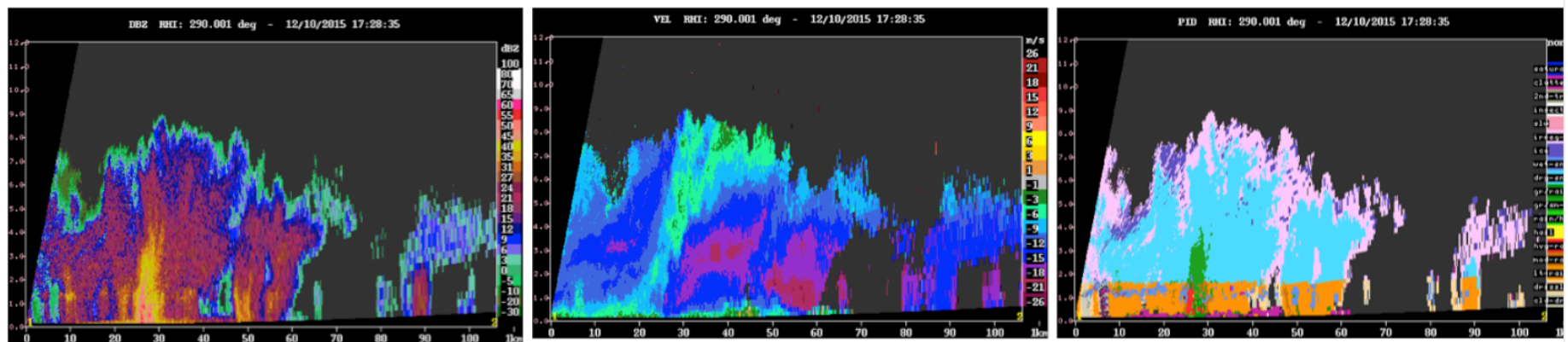
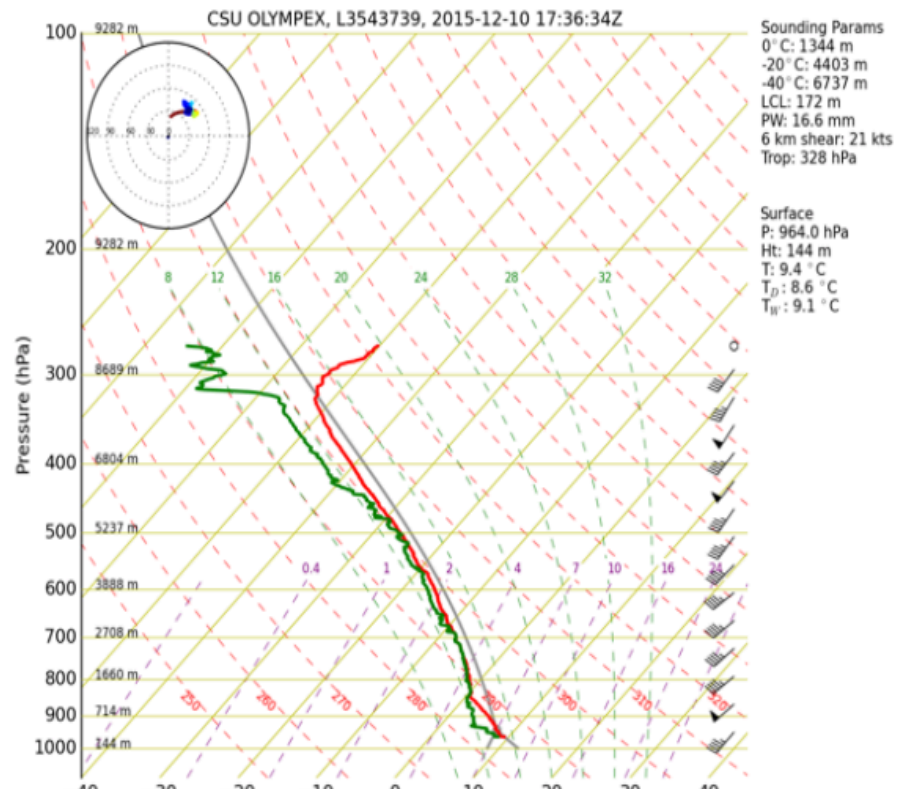
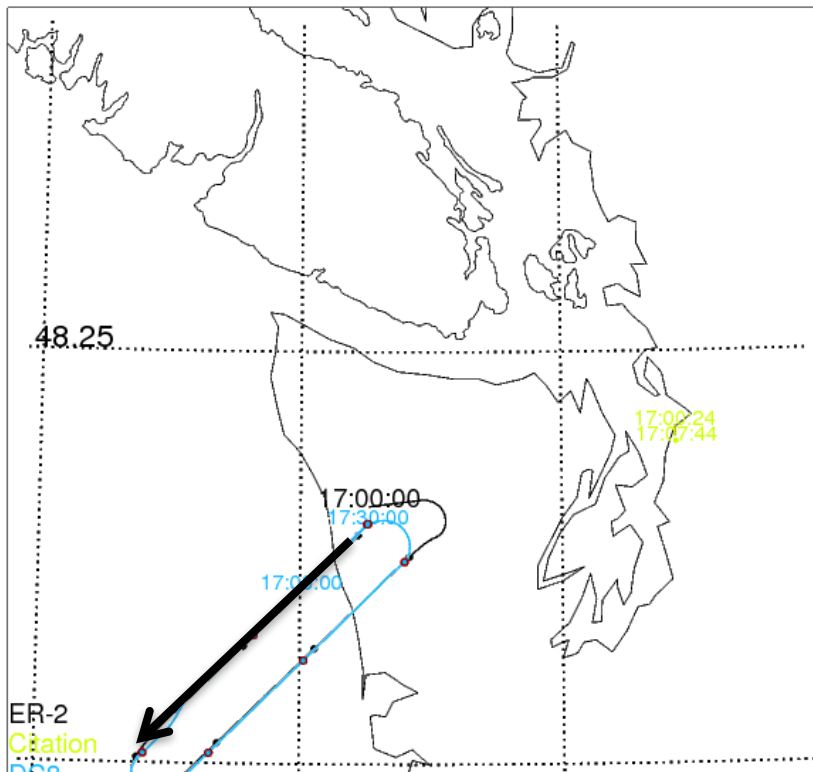
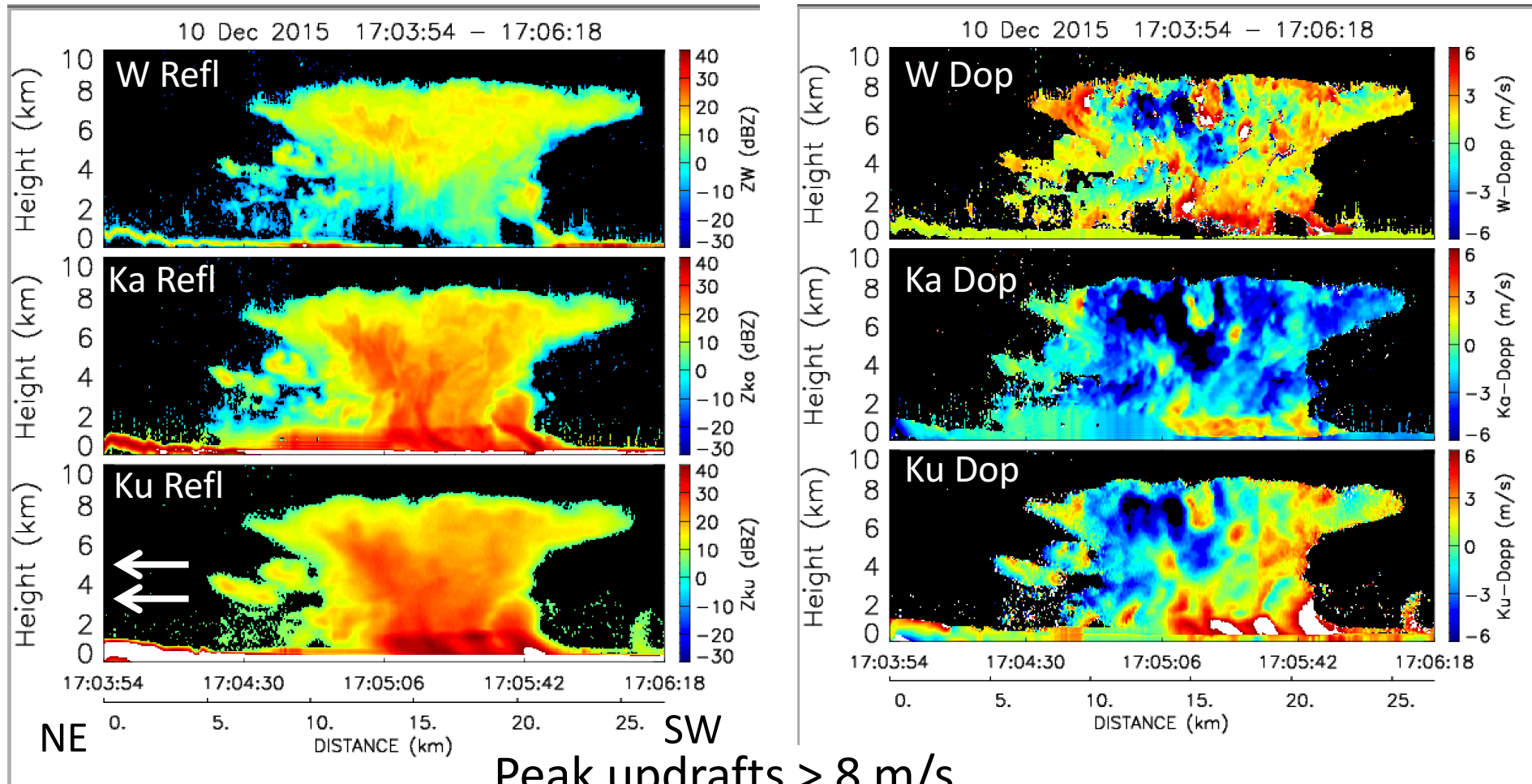


Figure 10. NPOL radar data obtained on 10 December 2015.

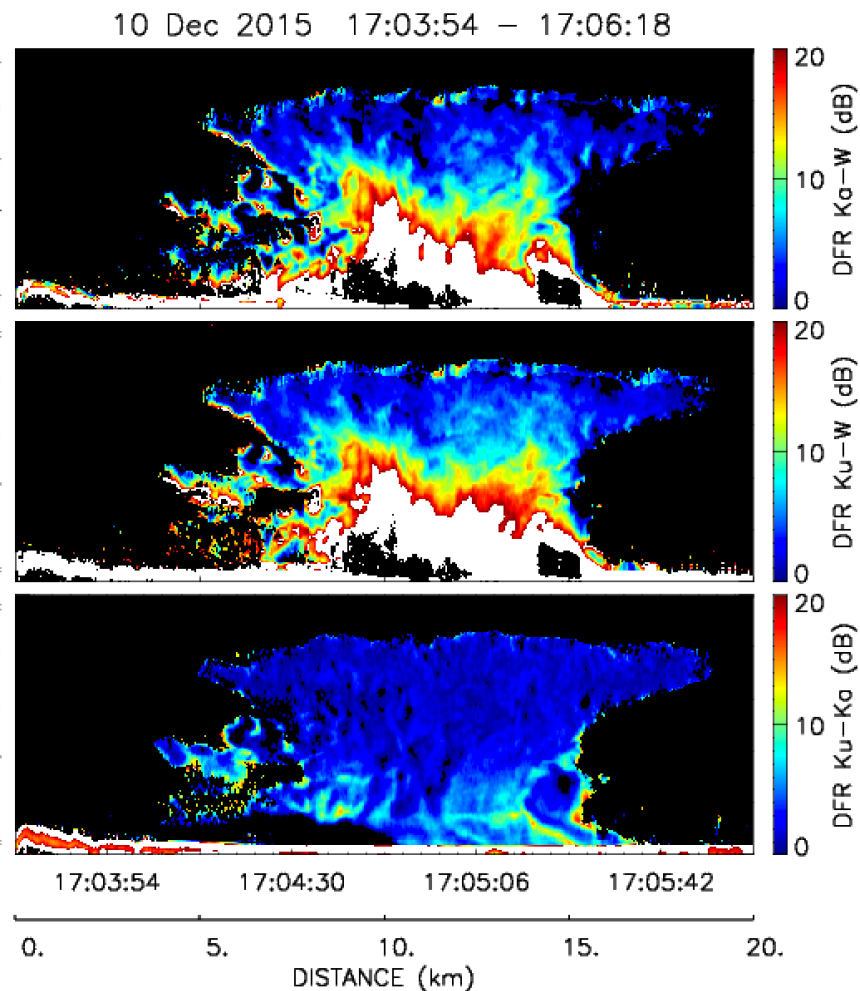
OLYMPEX 10 Dec 2015

Postfrontal Convection

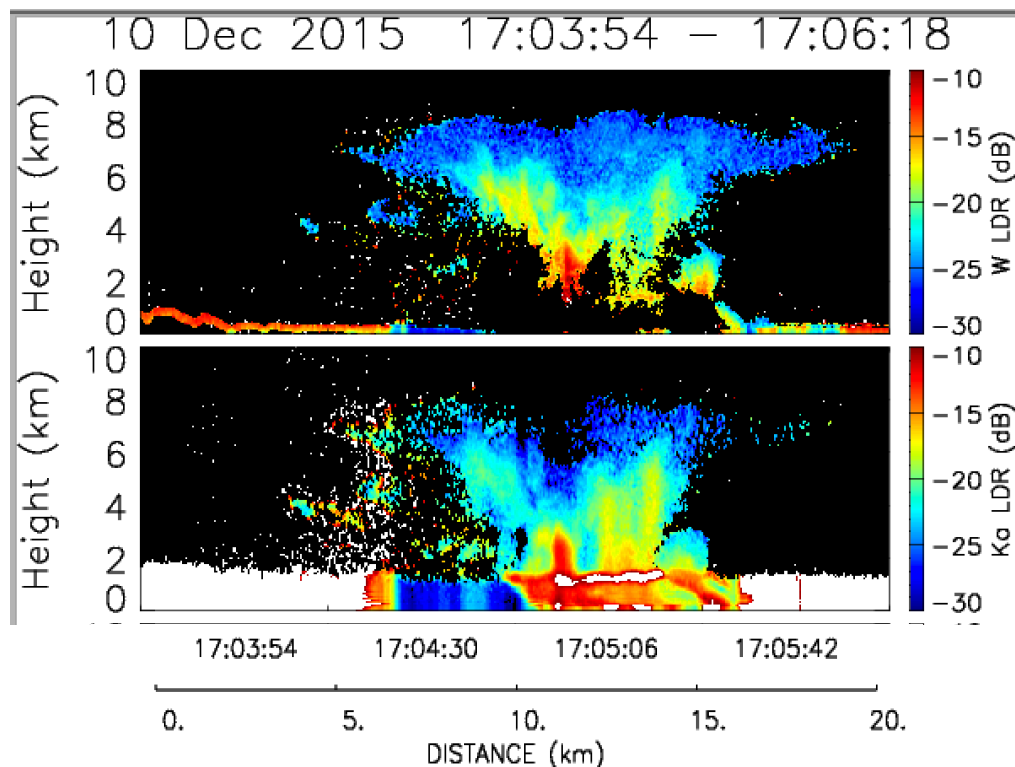


OLYMPEX 10 Dec 2015

DFR

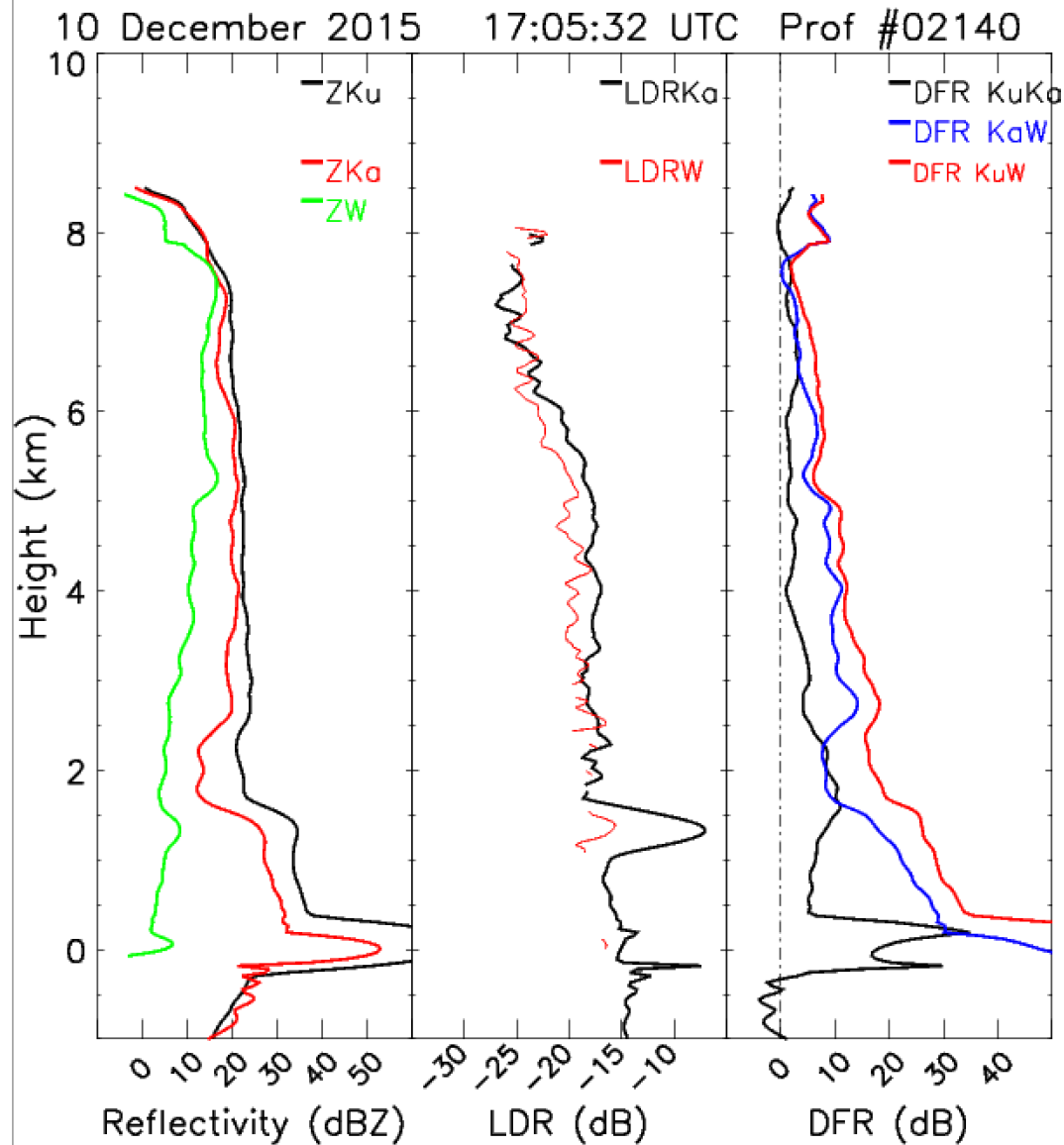


LDR



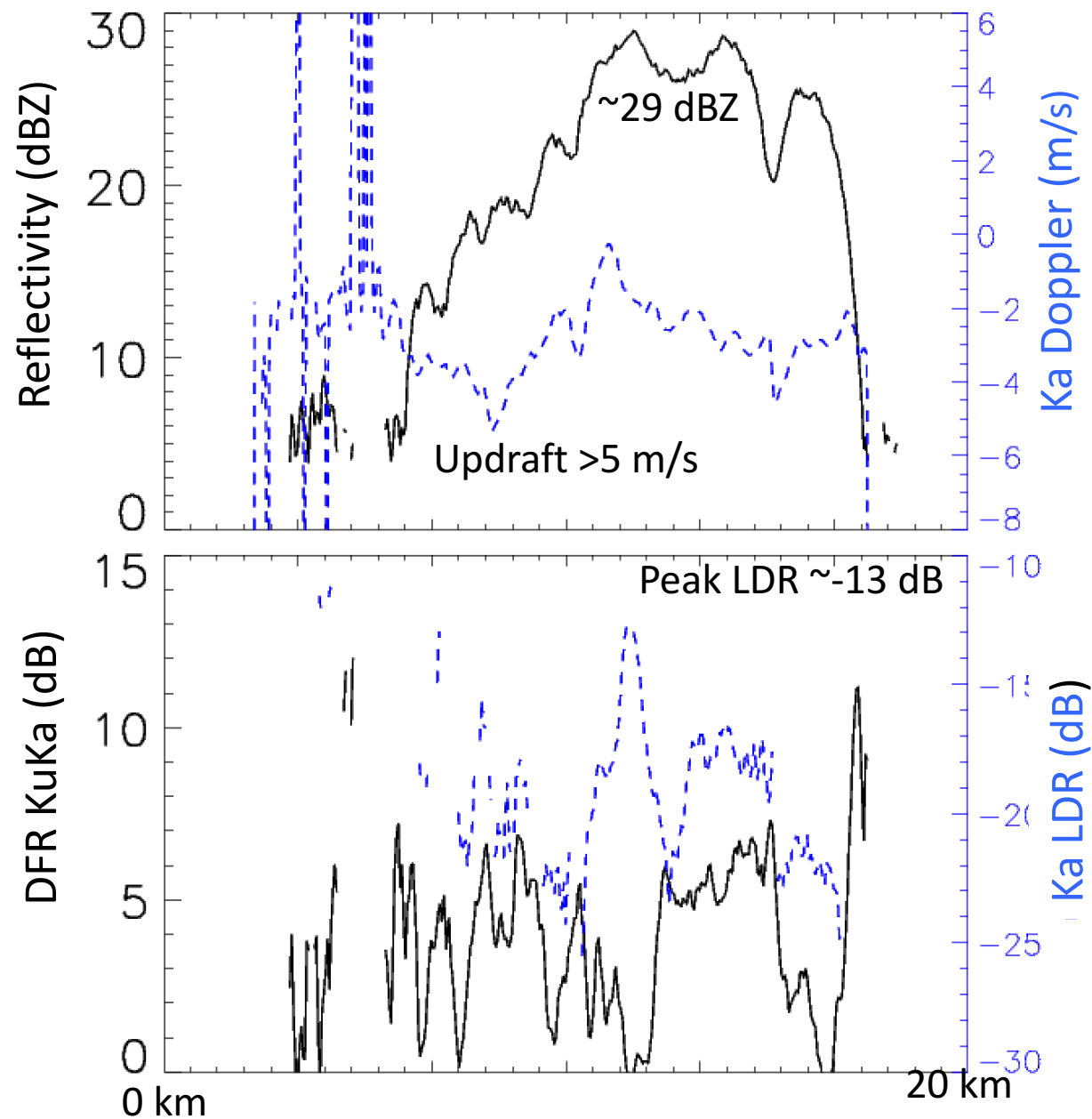
LDR columns at Ka-band and corresponding reflectivities suggest low density graupel, possibly wet falling out of updrafts above 3-4 km.

10 December 2015



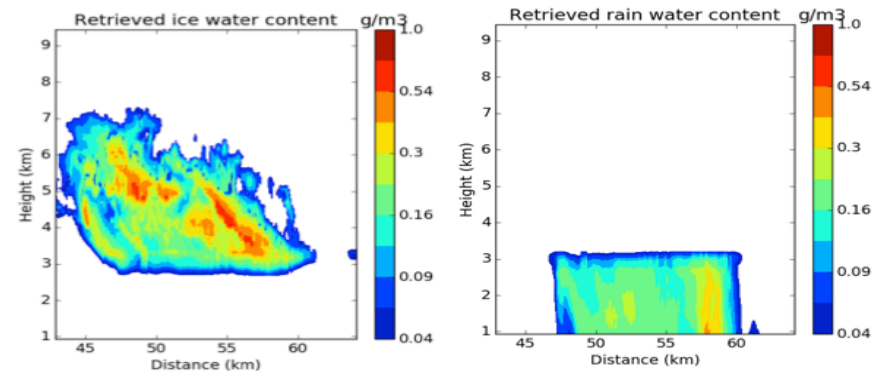
- Ka LDR \sim -15 dB
- Strong attenuation at W-band.
- “Dark band” at Ku and Ka-band suggesting large particles.
- Multiple scattering at W-band \rightarrow graupel?

OLYMPEX 10 Dec 2015 2.25 km altitude

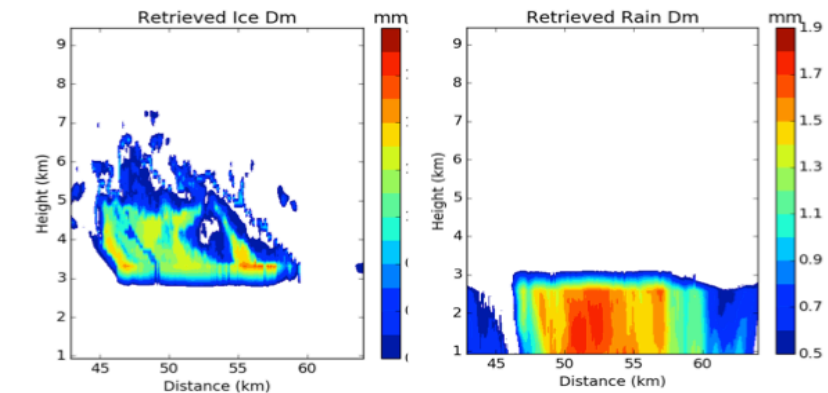


IPHEX Retrievals

- Example of observed and retrieved Ka/W band data from the IPHEX field campaign and based on Grecu et al. (2011, 2016) algorithm.
- The framework of this is capable of performing retrievals from radar and other sensors.
- More testing is required on a variety of data sets to evaluate its performance.

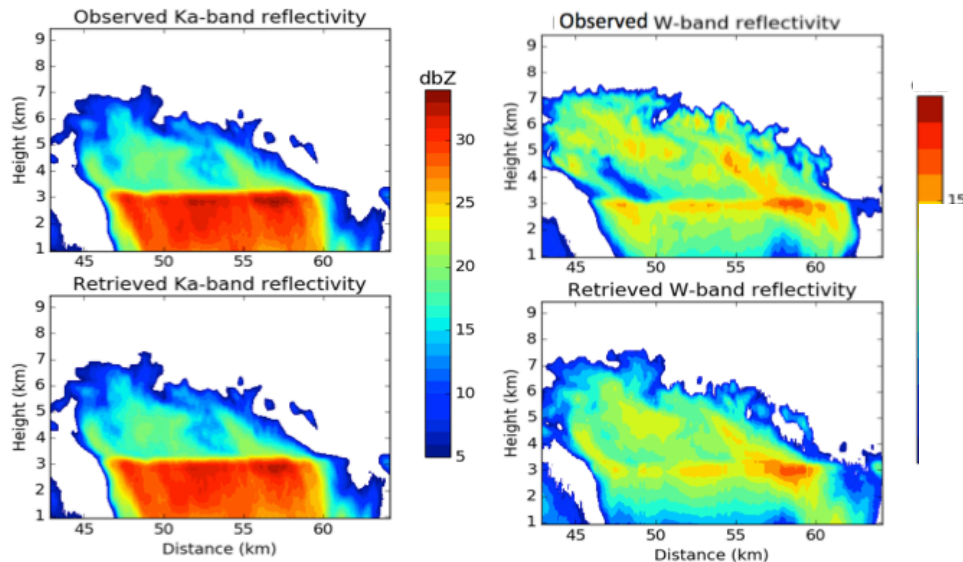


Retrieved ice and rain water content from reflectivity on left.



Retrieved mean diameter (Dm) and rain rate from reflectivity on left.

Courtesy of Mircea Grecu



Observed (top panels) and retrieved (bottom panels) reflectivity from CRS W-band and HIWRAP Ka-band on 12 June 2014 during the IPHEX field campaign. Mostly light stratiform rain is present during this flight line.

Summary

Work in progress:

- Use analysis framework set up to examine wider range of cases (e.g. orographic) with ER-2 measurements + Citation *in situ*, and S-band polarimetric radar.
- HID, vertical motions → relevant to latent heating algorithms
- Evaluate Grecu optimal estimation retrievals on a variety of IPHEX & OLYMPEx cases.
- DPR algorithm evaluation - e.g. DPR heavy precip flag.
- Collaboration with DPR, GMI, and combined algorithm developers.
- Quantify nadir LDR observations through 3D RT model (→ Ian Adam's poster yesterday)

Quick look ER-2 radar data at: <http://har.gsfc.nasa.gov>